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game fish as well. Unless long stretches of rivers are treated, or suitable barriers exist, re-invasion of undesirable fish occurs rapidly.

Catfish, however, may be taken readily with selective gear throughout much of the open water season, so it would be possible to harvest a portion of a catfish population in an attempt to stimplate the growth of the remaining fish. The possibility of rough fish removal, where economically feasible, could also be tried, either separately or in conjunction with the catfish removal. Careful scientific evaluation of the effects of the program would be a real contribution to catfish management.

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Spawning Periodicity of the River Carpsucker, *Carpiodes carpio*[1]

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Abstract: The sex ratio of river carpsuckers collected from the Des Moines River differed significantly from 1:1, females being most abundant. Spawning had already begun in early June and some fish were found ripe as late as August. No carpsuckers younger than age IV were found mature. All ripening carpsucker ovaries contained a group of eggs that seemed to be degenerating. It is not certain if carpsuckers spawn more than once in a season.

INTRODUCTION

Although the river carpsucker, *Carpiodes carpio* (Rafinesque), is abundant in many midwestern rivers, little is known about its life history and ecology. In this study, special attention was given to its mode of spawning.

Starrett (1948) found three sizes of eggs in the ovaries of ripe female carpsuckers and, from this, inferred that the carpsucker is an intermittent spawner (e.g., spawns more than once in a single season). Many other species of fish have been reported as intermittent spawners, but few studies have dealt specifically with this subject, and many questions remain un-

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answered. Ovaries were taken from carpsuckers throughout the summer and fall 1964, and the relationships of the different size groups of eggs within the ovary were studied.

METHODS OF FISH COLLECTION

All ovaries were obtained from fish collected from the Des Moines River in the vicinity of Luther Bridge, except the June 1 and June 3 collections made at the "high bridge" of the Chicago and Northwestern Railroad, approximately 14 stream miles upstream of the Luther Bridge. They were collected between early June to the end of September. All fish were captured with an electric shocking device operated from a boat and powered by a 230-volt, alternating current generator.

Most fish were placed directly into formalin (approximately 10%) in the field, and ovaries were removed and the fish sexed later in the laboratory.

SEX RATIO

Based on 452 individuals, the sex ratio of the river carpsucker in the study area differed significantly from 1:1 with a predominance of females (Table 1). The sex ratios for the various sampling periods do not differ significantly from each other (heterogeneity chi square, not significant at P = .05).

Table 1. Number of male and female carpsuckers by date, 1964

Date	6/30	7/1	7/14	7/18	7/28	7/31	8/13	8/18	9/3	9/9
Males	15	23	22	13	28	21	20	16	27	17
Females	24	27	26	28	17	25	32	25	25	22

Totals: 201 males
251 females
Pooled chi square = 5.53* ($P < .025$)
Heterogeneity chi square = 11.49 ($P < .25$)

SIZE AND AGE AT MATURITY

Ovaries were weighed to the nearest gram. All ovaries appearing ripe or partially ripe were weighed; however, ovaries from unripe fish were often very small and not always weighed. The percentage of the body weight made up by the ovaries was calculated for each fish. Since the fish were weighed in the field, but the ovaries were weighed in the laboratory after being in formalin, some bias might exist in these calculations.

Based on the appearance of the ovaries and an examination of ovary weights (as percentages of body weights), an ovary weight of 3.0% of the body weight was arbitrarily designated as the separating point between fish considered ripe or partially ripe and those unripe. Unripe fish may have ripened later in the season or may not have reached sexual maturity. Using this criterion, the smallest fish classified as ripening measured 8.9 inches in total length. No females younger than age IV, as determined by examination of the scales, were found in a ripening or ripe condition.

Evidence that largest and oldest females ripen earliest is found in the mean weights of ripe or partially ripe females (Table 2). However, the fact that the June 1 and June 3 samples were collected in a different area from the others may be partly responsible for the high mean weight of those females.

Table 2. Mean weight of ripening females by date, 1964

Dates	Number of fish	Mean weight (grams)	Range
6/1 & 6/3	7	551	422 - 737
6/16 & 6/18	16	267	153 - 513
6/30 & 7/1	20	263	180 - 513
7/14 & 7/18	8	247	132 - 482

Spawning Period

Two criteria were used to determine spawning intensity for each collection date (Table 3). These were: the percentage of ripe or partially ripe females on that date and the mean ovary weights (as percentages of body weights) of the fish ripening on that date. Spawning was already underway early in June and was greatest in mid-June to early July. It tapered off later in July and seemed to have almost ended at the end of July. Nevertheless, two ripe females were collected in mid-August. There was no clearly defined spawning peak, and female carpsuckers did not ripen synchronously. Ripe males were identified in the field by extrusion of milt when stripped. Ripe males were found throughout June, but by early July, few could be stripped, and by mid-July, the number of ripe males in the sample was negligible. This may be related to the fact that, in many species of fish, males ripen earlier in the season than females (Hoar, 1957).

Table 3. Spawning intensity of river carpsuckers, 1964

Date	Number of ripe fish	Mean ovary weights (as percentages of body weights)	Total number of females	Percentage of females ripening
6/1	2	7.53	19*	10.5*
6/3	5	12.52	27*	18.5*
6/16	6	9.36	19*	31.2*
6/18	11	14.27	30*	36.6*
6/30	5	7.76	24	20.8
7/1	12	6.97	27	44.4
7/14	4	4.91	26	15.4
7/18	2	6.70	28	7.1
7/28	1	3.14	17	5.9
7/31	1	4.34	25	4.0

* Sexing of fish was questionable on these dates.

Formalin hardened the eggs and they could be separated from the ovarian membrane by rolling the ovary between the thumb and forefingers. The separated eggs were dropped into a container of water. The eggs were allowed to settle to the bottom, and the excess water was poured off. The eggs with a small amount of water were poured into a petri dish and examined with a scale projector as described by Van Oosten, Deason, and Jobes (1934), at a magnification of 44X.

Three size groups of eggs were present in a ripe carpsucker ovary. In the early stages of ripeness, the largest two size groups were difficult to distinguish (Fig. 1A, 2A). The smallest size group was most numerous and contained very small, yolkless, transparent ova. These ova were not measured. When the largest two sizes of ova were difficult to distinguish, about 300 were measured, and the resulting ova diameter frequencies were plotted. Separation of the two modes was then possible, although somewhat arbitrary. Intermediate and large ova (the largest sizes) were easily distinguished when taken from ripe ovaries (Fig. 1E, 2B). When the two larger sizes were easily separable, about 50 of the large and 30 of the intermediate ova were measured and the average diameter was calculated for each group. If plotting of the diameter frequencies was necessary for separation, the mean diameters were computed from the resulting number of eggs in each mode. Since the ova were not perfectly spherical, the diameter of each ovum was measured along a horizontal axis. Clark (1931) and Carbine (1943) found this method unbiased. The proportion of intermediate ova to all ova (excluding the smallest size group) was also determined.

To determine if the ova were the same in size and relative proportions from all parts of the ovary, samples from the anterior, middle, and posterior sections were compared. Mean diameters of large and intermediate eggs, from each section and percentage of small eggs, agreed closely (Behmer, 1965). Carbine (1943) found that ova from the middle of the ovary of northern pike, *Esox lucius,* were slightly larger than ova taken from the ends. Clark (1931) found no difference in the relative proportions of ova from different parts of the ovary of California sardine, *Sardina caerulea.*

Clark (1931) found no evidence of egg shrinkage or expansion due to formalin. Vladykov (1956), however, stated that formalin shrinks ovaries and eggs slightly. If this is the case, all egg diameters given in the following section may be slightly smaller than they would have been if the eggs had been measured before preservation.

Results and Discussion

Three size groups of eggs were present in a ripening carpsucker ovary. The smallest eggs are transparent in contrast to

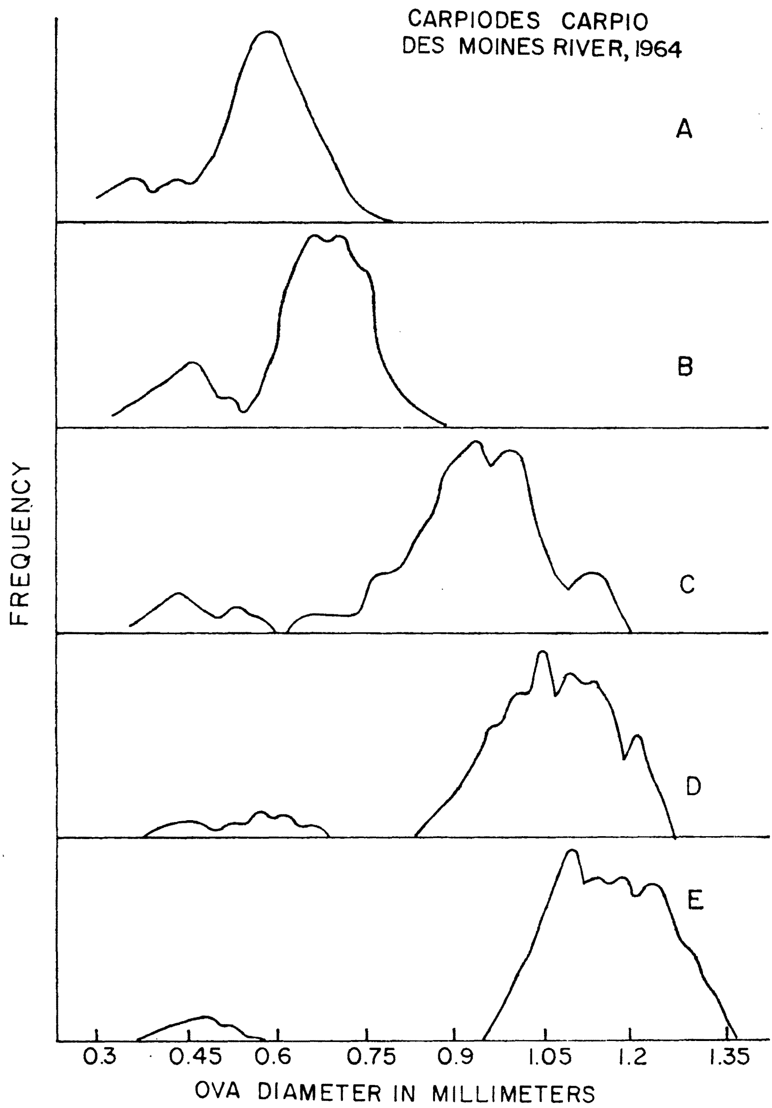

Figure 1. Diameter frequencies of intermediate and large ova of five carpsuckers illustrating stages in development. A and B are early stages of maturity when large and intermediate eggs are difficult to separate. Stage E is believed to represent eggs which are almost ready to spawn. The curves have been smoothed by a moving average of three.

the larger ones. The transparent ova start to appear yellow or light tan when they are approximately 0.3 mm in diameter. At about 0.4 millimeters, they are opaque and remain so until mature. Cunningham (1895) attributed this transition from transparency to opaqueness wholly to yolk formation.

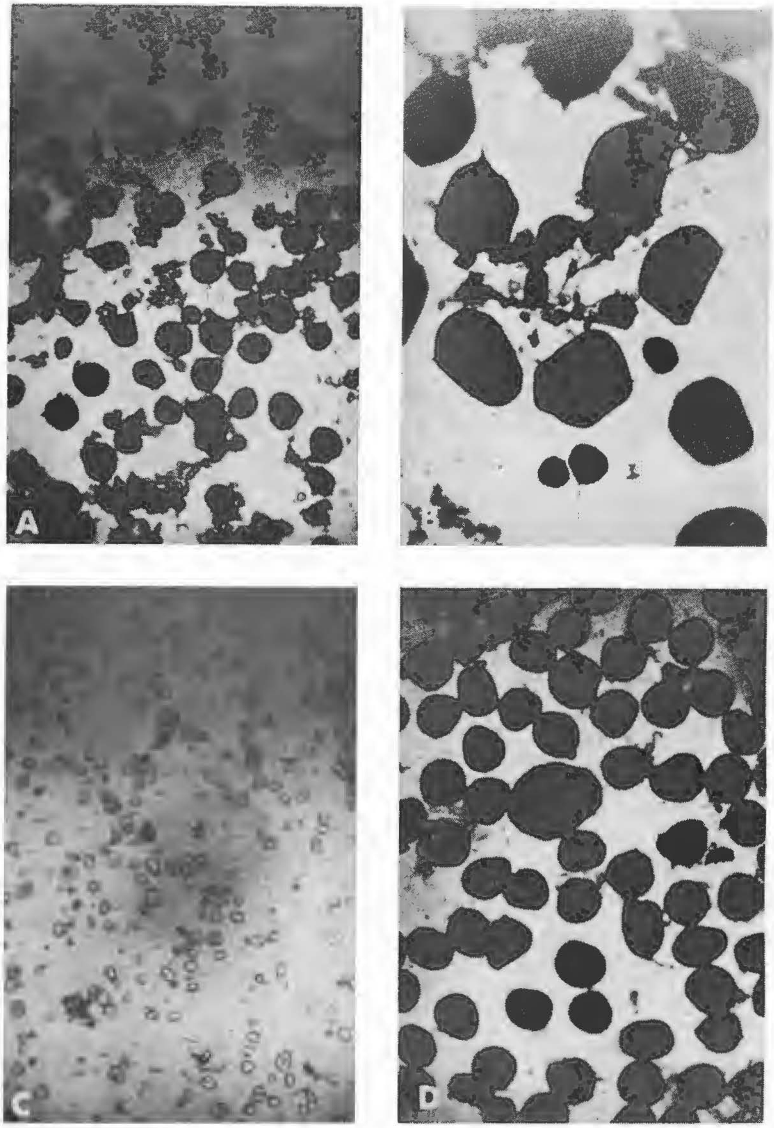

Figure 2. Carpsucker ova as seen on the scale projector. Ova from a fish in early stages of ripening (A). Ova from a ripe fish (B). Ova from a spawned fish with only transparent ova present (C). Ova from a fish with a few residual large eggs—explanation in text (D).

Five stages in the growth of ova to maturity are represented in Fig. 1. The relative frequencies of the two larger groups of eggs can be seen from the graphs. The transparent eggs were measured in only one individual and are not shown in the graphs. Transparent eggs ranged in diameter from less than

0.07 mm to about 0.3 mm, with a mode at approximately 0.15 mm. Stage A in Fig. 1 corresponds approximately to Fig. 2A and stage E to Fig. 2B.

The large and intermediate eggs were difficult to visually set apart in early stages of ripening, when the average diameter of the large eggs was less than approximately 0.5 mm. All ovaries with an average diameter of large eggs greater than 0.5 mm also contained intermediate eggs. The intermediate eggs were at first assumed to represent a reserve stock for a second spawning. As the spawning season progressed, however, the intermediate eggs were still present in all ripening ovaries. The situation changed abruptly at the end of July when all but one of the ovaries examined contained only transparent eggs (Fig. 2C). The number of ovaries examined at each sampling date corresponds to the number of females collected on those dates (Table 1). Eggs from all ovaries considered ripe or partially

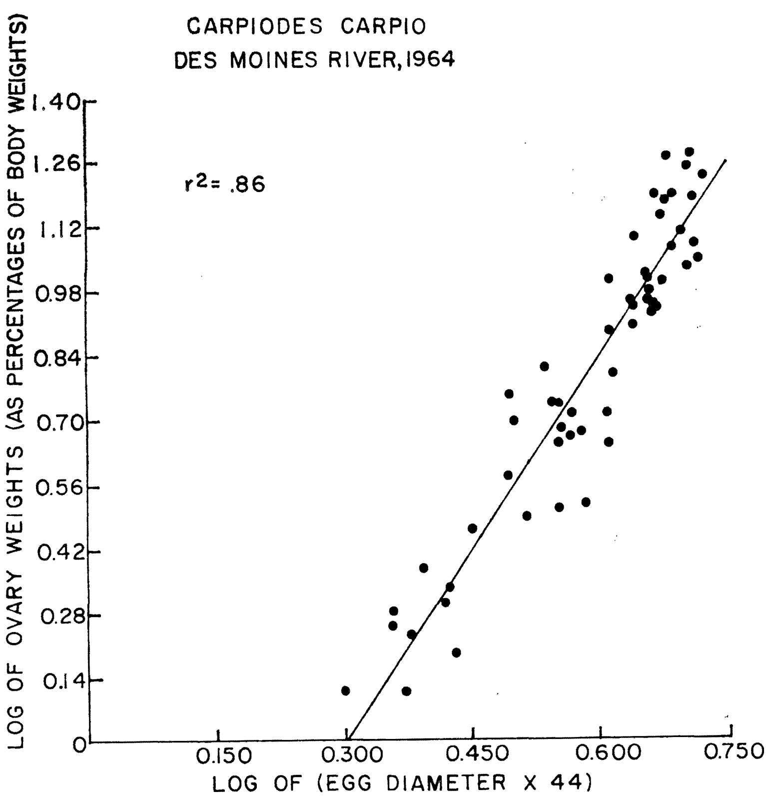

Figure 3. Log of ovary weights (as percentages of bodyweights) plotted against log of (egg diameter × 44). Equation for regression line in text.

ripe were examined and measured under the scale projector. Similar examination was also made for many unripe ovaries.

A close relationship existed between the average diameter of the large eggs and the ovary weights (as percentages of body weight) (Fig. 3). This relationship was made linear by transformation of the data to logarithms. An approximate regression line was calculated by using large sample methods (Snedecor, 1956, pp. 210-211):

$$\text{log ovary weights (as percentages of body weights)} = -0.84 + 2.78 \log (\text{egg diameter} \times 44).$$

Since in the carpsucker ovary the intermediate eggs are much fewer than the large eggs, we would expect the second spawning to be much lighter than the first if intermediate eggs are to constitute the eggs for a second spawning. A fish spawning for the second time should then have been much lighter in ovary weight (as a percentage of body weight) than a fish spawning for the first time (considering fish with similar mean diameters of large eggs). This would result in large deviations from the calculated regression line since all ripening carpsuckers were included in the graph. In no case, do we find this true.

The most logical explanation for the presence of intermediate eggs is that they represent eggs which started developing but failed to develop to maturity. Vladykov (1956) noted the failure of some eggs to develop to maturity in the brook trout, *Salvelinus fontinalis*. He termed the eggs which failed to develop "atretic eggs" because they were being resorbed by the fish. He hypothesized that these eggs act as a "safety valve" for the fish, since if all eggs which started development should mature, the fish would not have the capacity to contain all the eggs.

A significant correlation ($r = -.38$; $P < .025$) was found between the average diameter of large eggs and percentage of intermediate eggs (Fig. 4). The percentage of intermediate eggs decreases as the large eggs mature. Vladykov found a decrease in the number of atretic eggs as the fish matured and attributed this decrease to the resorbtion of some of these eggs by the fish.

It might seem from this that carpsuckers spawn only once a season. However, some evidence exists that some females may have spawned more than once. Three fish collected contained only a few large eggs, about 1.2 millimeters in diameter, but the ovaries were filled with smaller, ripening eggs (Fig. 3D). The large eggs appeared to be left over from a previous spawning. This strongly suggested that these fish had spawned once and were ripening for a second spawning. The developing eggs were not the intermediate eggs from the previous spawning because all three of these fish were above average in ovary weights (as percentages of body weights) (Fig. 3). A count of

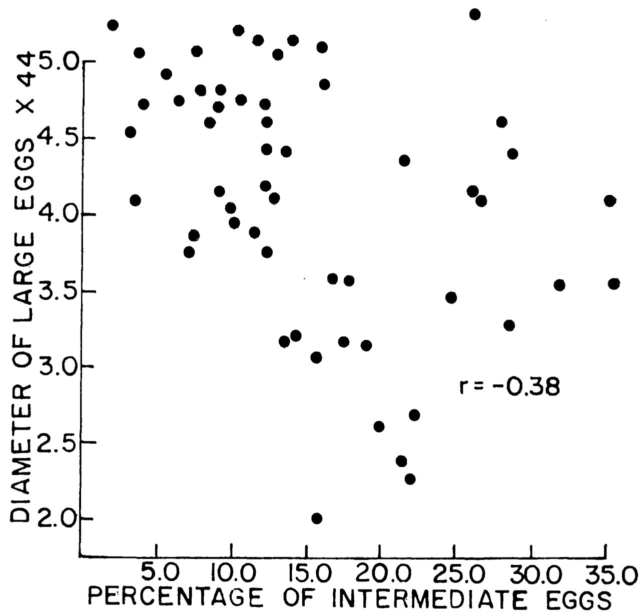

Figure 4. Number of intermediate eggs (as a percentage of intermediate and large eggs) plotted against mean diameter of large eggs × 44. r = −0.38.

eggs in one of these females revealed an above-average number of eggs when compared with Buchholz's graph (1957) of egg numbers against size of fish.

Vladykov (1956) states that brook trout sometimes retained eggs in the body cavity from one year to the next without resorbing them. The few large eggs found in three carpsuckers might have been left over from the previous spawning a year earlier. However, one of the fish which contained "leftover" large eggs extruded some of them at the time of collection when it was stripped. Later examination of the ovaries revealed a few large eggs and many ripening eggs. The fact that it was possible to easily strip a number of large eggs from the fish makes it more difficult to believe that they were left from the previous year.

If the fish found with a few residual large eggs were ripening for the second time in the same season, the batch of eggs ripening must have developed from the stock of transparent eggs. The intermediate eggs would not have been numerous enough.

We are faced with two hypotheses: Either the carpsuckers spawn more than once, and the large residual eggs represent eggs from a previous spawning in the same year; or, the residual eggs are from a previous year, and the carpsuckers spawn only once in a season. If the carpsuckers spawned more than once, the spawnings would have had to have been almost equal in magnitude to produce such a high coefficient of determination as in Figure 2 ($r^2 = .86$). Unfortunately, the gross appearance of the residual large eggs seems to offer few clues. The residual eggs are not white like resorbing eggs, nor are they the dull yellow of maturing eggs. They are opaque and orange. Further study is needed.

After spawning appeared to have ended in late July, two females were still found ripe in August. All other ovaries examined showed only transparent eggs or transparent eggs and a new mode of eggs starting to grow. The latter are believed to represent eggs for next year's spawning. Ovaries examined in late September contained only transparent eggs or transparent eggs, plus a mode of developing eggs. The developing eggs had reached an average diameter of approximately 0.5 mm in one individual at this time. Developing eggs were smaller in all other individuals between the end of July and the end of September, with the exception of the two females which were ripe in August. No residual large eggs were noticed in any of the ovaries examined after the end of the spawning season. The number of ovaries examined was considerably fewer than during the spawning season.

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